

**DETAILED PROJECT REPORT  
WITH ENVIRONMENTAL ASSESSMENT**

**SECTION 205 FLOOD DAMAGE REDUCTION STUDY**

**MAD CREEK  
MUSCATINE, MUSCATINE COUNTY, IOWA**

**APPENDIX J  
STRUCTURAL ANALYSIS**

**CONTENTS**

<b>Subject</b>	<b>Page</b>
1. General .....	J-1
2. Structural Computations .....	J-2



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**APPENDIX J  
STRUCTURAL ANALYSIS**

**1. GENERAL**

Preliminary structural analysis was performed on the existing floodwall to determine its adequacy to raise its height by 2 feet. Overturning and internal structural strength analyses were performed on sections of floodwall that exhibited the greatest potential for failure. Conservative values for soil properties were utilized in the calculations. Calculations completed on the existing floodwall are provided on the following pages in this appendix.

The analysis found that the internal structural strength at the interface of the sheet pile and concrete wall did not meet the EM guidelines. The use of a combined load factor of 2.21 is required, however, calculations at the probable worse case location indicate only a load factor of 1.7 can be supported when a 2-foot raise is added to the top of the existing floodwall. An earth berm or concrete buttresses will be added as needed along the landside of the floodwall to provide the required additional strength. The additional support is considered to be minimal in cost and should be more than covered by the 25% contingency placed on the floodwall line item.

All other preliminary computations indicated that the existing floodwall strength is adequate to support the addition of 2 feet to its height.

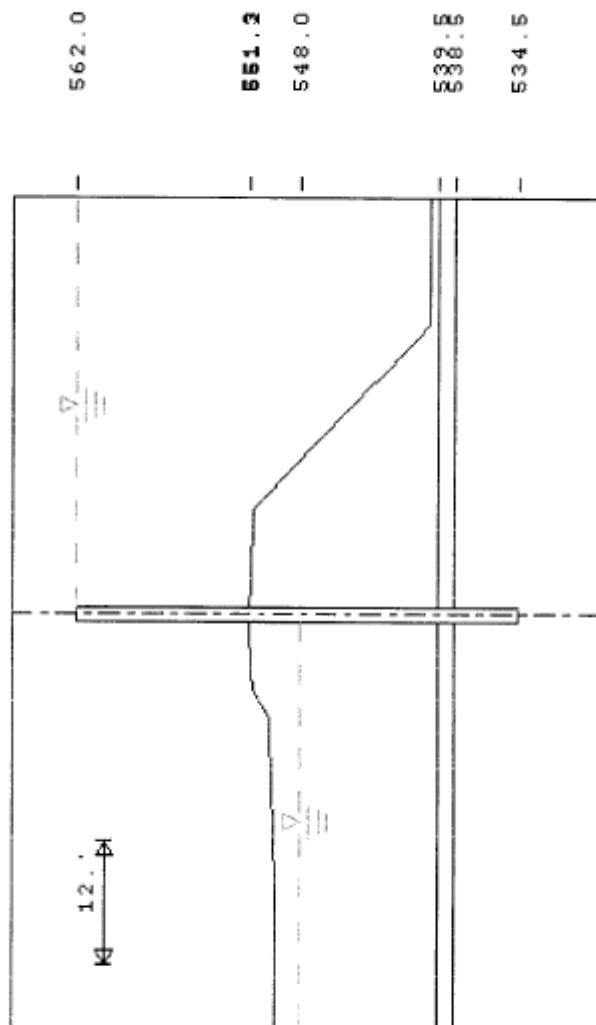
## 2. STRUCTURAL COMPUTATIONS

MADIWALL.IN2  
10 12FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
20 FLOOD CONTROL PROJECT MUSCATINE IOWA  
30 WATER TO TOP OF WALL  
40 CONTROL CANTILEVER ANALYSIS  
50 WALL 562.0 534.5 30000000.0 184.20  
60 SURFACE RIGHTSIDE 3 0.0 551.25 10.0 551.0 28.0 540.0  
70 SURFACE LEFTSIDE 4 0.0 551.175 7.0 551.0 10.0 550.0 25.0 548.5  
80 SOIL BOTH STRENGTHS 3  
90 130.0 120.0 35.0 0.001 17.0 0.0001 539.5 0.0 rubble  
100 130.0 115.0 0.001 400.0 0.001 0.0001 538.5 0.0 CL lean clay  
110 125.0 115.0 35.0 0.001 14.0 0.0001 SM silty clay  
150 WATER ELEVATIONS 62.4 562.0 548.0 551.25 Automatic  
160 FINISH

no frequency adjustment

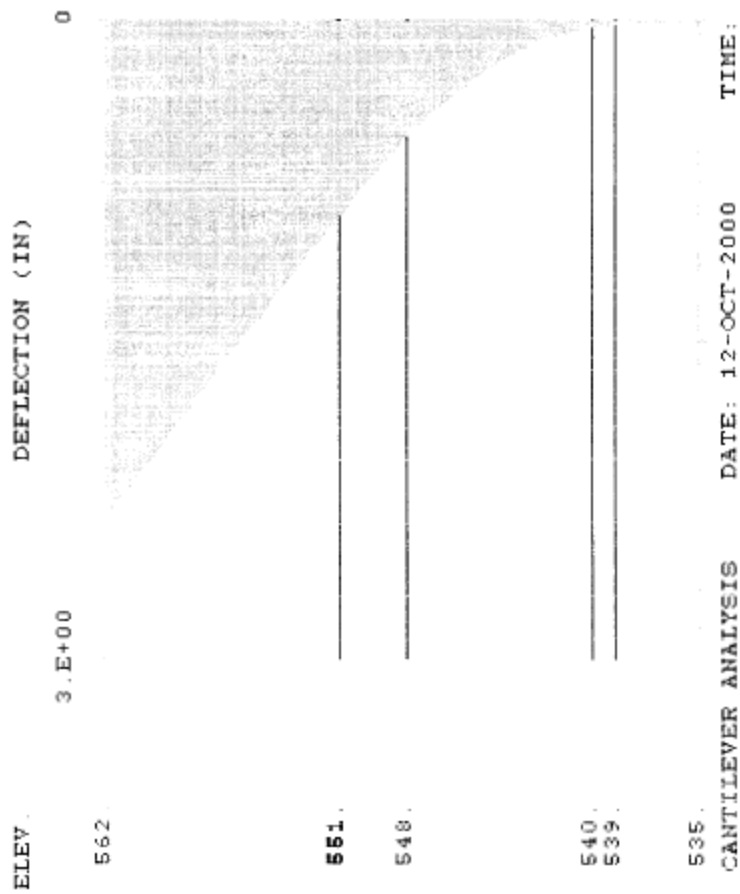
'2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
 'FLOOD CONTROL PROJECT MUSCATINE IOWA

ELEV.

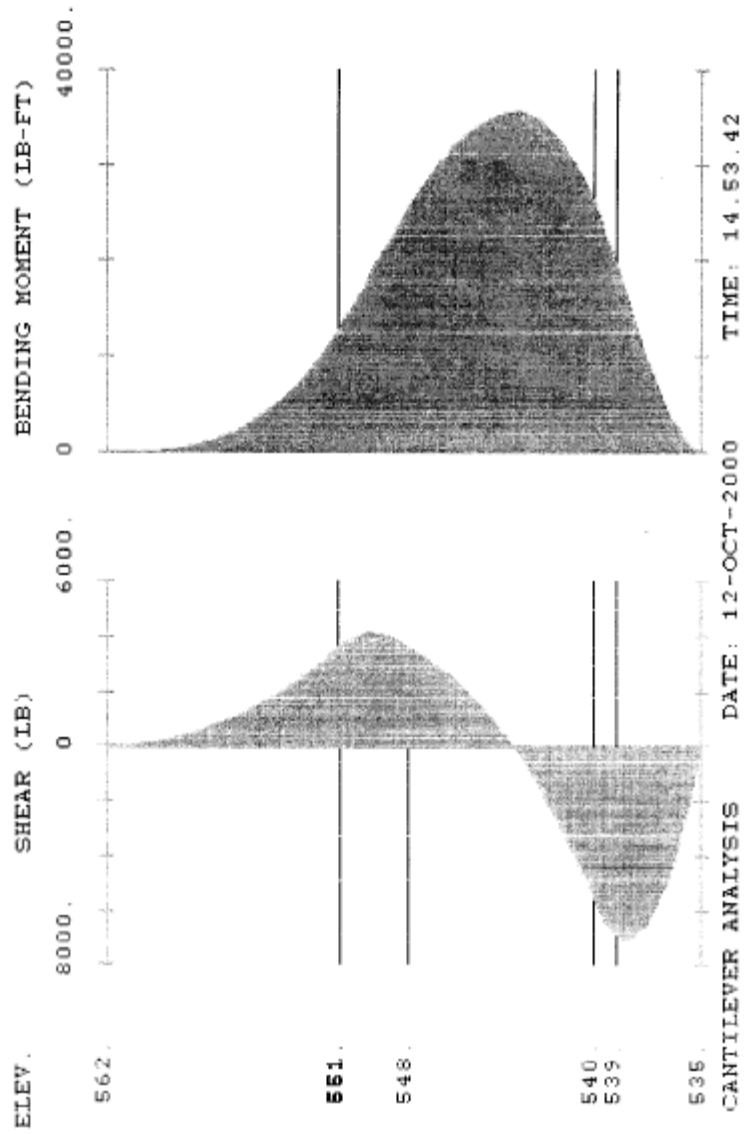


\*\*\*\*\* INPUT GEOMETRY \*\*\*\*\*  
 DATE: 12-OCT-2000 TIME: 14.52.23

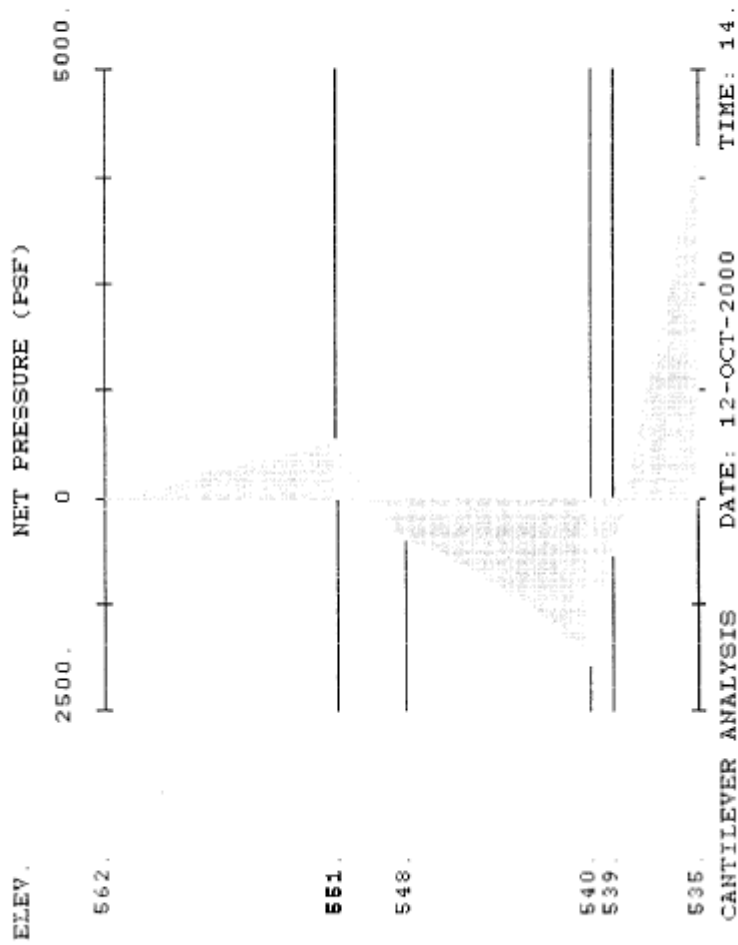
'2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
'FLOOD CONTROL PROJECT MUSCATINE IOWA



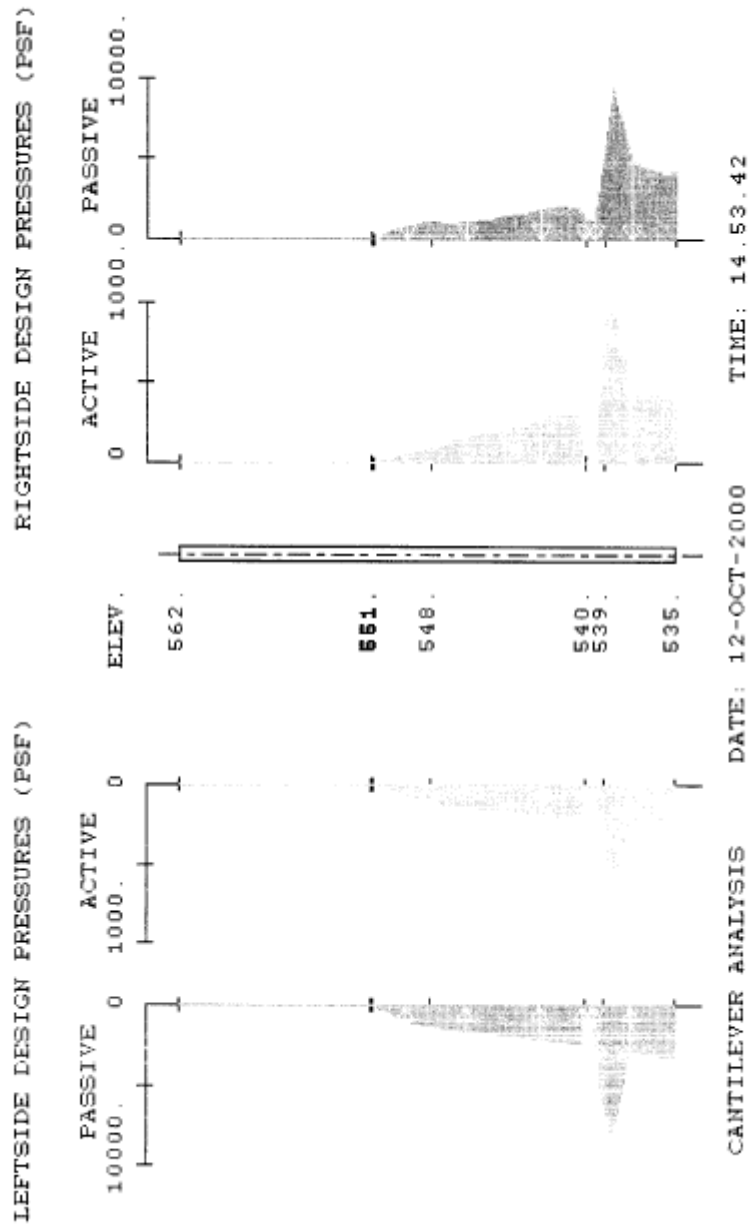
'2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
'FLOOD CONTROL PROJECT MUSCATINE IOWA



'2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
'FLOOD CONTROL PROJECT MUSCATINE IOWA



'2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
'FLOOD CONTROL PROJECT MUSCATINE IOWA



# MADIWALL EX2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS

BY CLASSICAL METHODS

DATE: 12-OCT-2000

TIME: 14.51.52

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\* INPUT DATA \*

\*\*\*\*\*

I.-HEADING:

\*2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK

\*FLOOD CONTROL PROJECT MUSCATINE IOWA

\*WATER TO TOP OF WALL

II.-CONTROL

CANTILEVER WALL ANALYSIS

SAME FACTOR OF SAFETY APPLIED TO ACTIVE AND PASSIVE PRESSURES.

III.-WALL DATA

ELEVATION AT TOP OF WALL = 562.00 (FT)

ELEVATION AT BOTTOM OF WALL = 534.50 (FT)

WALL MODULUS OF ELASTICITY = 3.00E+07 (PSI)

WALL MOMENT OF INERTIA = 184.20 (IN\*\*4/FT)

IV.-SURFACE POINT DATA

IV.A.-RIGHTSIDE

DIST. FROM ELEVATION

WALL (FT) (FT)

.00 551.25

10.00 551.00

28.00 540.00

IV.B.- LEFTSIDE

DIST. FROM ELEVATION

WALL (FT) (FT)

.00 551.18

7.00 551.00

10.00 550.00

25.00 549.50

V.-SOIL LAYER DATA

V.A.-RIGHTSIDE LAYER DATA

		ANGLE OF		ANGLE OF		<-SAFETY->			
		SAT. MOIST INTERNAL COH-		WALL ADH-		<-BOTTOM->		<-FACTOR->	
WGHT.	WGHT.	FRICION	ESION	FRICION	ESION	ELEV.	SLOPE	ACT.	PASS.
(PCF)	(PCF)	(DEG)	(PSF)	(DEG)	(PSF)	(FT)	(FT/FT)		
130.00	120.00	35.00	.0	17.00	.0	539.50	.00		
130.00	115.00	.00	400.0	.00	.0	538.50	.00		
125.00	115.00	35.00	.0	14.00	.0				

V.B.- LEFTSIDE LAYER DATA

		ANGLE OF		ANGLE OF		<-SAFETY->			
		SAT. MOIST INTERNAL COH-		WALL ADH-		<-BOTTOM->		<-FACTOR->	
WGHT.	WGHT.	FRICION	ESION	FRICION	ESION	ELEV.	SLOPE	ACT.	PASS.
(PCF)	(PCF)	(DEG)	(PSF)	(DEG)	(PSF)	(FT)	(FT/FT)		
130.00	120.00	35.00	.0	17.00	.0	539.50	.00		
130.00	115.00	.00	400.0	.00	.0	538.50	.00		
125.00	115.00	35.00	.0	14.00	.0				

VI.-WATER DATA

MADIWALLEX2

UNIT WEIGHT = 62.40 (PCF)  
RIGHTSIDE ELEVATION = 562.00 (FT)  
LEFTSIDE ELEVATION = 548.00 (FT)  
SEEPAGE ELEVATION = 551.25 (FT)  
SEEPAGE GRADIENT = AUTOMATIC

VII.--SURFACE LOADS  
NONE

VIII.--HORIZONTAL LOADS  
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS  
BY CLASSICAL METHODS  
DATE: 12-OCT-2000 TIME: 14.53.42

\*\*\*\*\*  
\* SUMMARY OF RESULTS FOR \*  
\* CANTILEVER WALL ANALYSIS \*  
\*\*\*\*\*

I.--HEADING

'2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
'FLOOD CONTROL PROJECT MUSCATINE IOWA  
'WATER TO TOP OF WALL

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

FACTOR OF SAFETY : 1.28 > 1.25 *unacceptable - see figure 10.16*

MAX. BEND. MOMENT (LB-FT) : 35725.  
AT ELEVATION (FT) : 543.25

MAXIMUM DEFLECTION (IN) : 2.3182E+00  
AT ELEVATION (FT) : 562.00

SEEPAGE GRADIENT : .4628

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS  
BY CLASSICAL METHODS  
DATE: 12-OCT-2000 TIME: 14.53.42

\*\*\*\*\*  
\* COMPLETE RESULTS FOR \*  
\* CANTILEVER WALL ANALYSIS \*  
\*\*\*\*\*

I.--HEADING

# MADIWALLEX2

2FT RAISE OF TYPICAL I-WALL SECTION AT MAD CREEK  
FLOOD CONTROL PROJECT MUSCATINE IOWA  
WATER TO TOP OF WALL

## II.-RESULTS

ELEVATION (FT)	BENDING		NET		PRESSURE
	MOMENT (LB-FT)	(LB)	SHEAR (IN)	DEFLECTION (PSF)	
562.00	0.	0.	2.3182E+00	.00	
561.00	10.	31.	2.1847E+00	82.40	
560.00	83.	125.	2.0512E+00	124.80	
559.00	281.	281.	1.9178E+00	187.20	
558.00	666.	499.	1.7844E+00	249.60	
557.00	1300.	780.	1.6512E+00	312.00	
556.00	2246.	1123.	1.5185E+00	374.40	
555.00	3567.	1529.	1.3864E+00	436.80	
554.00	5325.	1997.	1.2555E+00	499.20	
553.00	7582.	2527.	1.1263E+00	561.60	
552.00	10400.	3120.	9.9946E-01	624.00	
551.25	12920.	3608.	9.0642E-01	670.80	
551.18	13192.	3656.	8.9723E-01	675.46	
551.18	13182.	3656.	8.9723E-01	675.45	
551.00	13842.	3767.	8.7588E-01	682.67	
550.18	17107.	4095.	7.7715E-01	202.38	
550.00	17826.	4123.	7.5665E-01	119.60	
549.71	19021.	4140.	7.2318E-01	.00	
549.36	20490.	4114.	6.8268E-01	-147.12	
549.00	21940.	4036.	6.4300E-01	-294.25	
548.00	25800.	3854.	5.3819E-01	-469.90	
547.00	29201.	3132.	4.3745E-01	-572.70	
546.00	32028.	2486.	3.4782E-01	-899.94	
545.00	34148.	1723.	2.6819E-01	-846.73	
544.00	35921.	798.	1.9921E-01	-1003.52	
543.00	35689.	-290.	1.4128E-01	-1170.99	
542.00	34785.	-1544.	9.4488E-02	-1338.05	
541.00	32542.	-2875.	5.8534E-02	-1523.72	
540.00	28769.	-4607.	3.2716E-02	-1740.06	
539.65	27042.	-5274.	2.5866E-02	-2070.17	
539.56	26553.	-5458.	2.4257E-02	-1959.81	
539.50	26230.	-5571.	2.3258E-02	-1886.79	
539.43	25853.	-5694.	2.2154E-02	-1807.79	
539.15	24168.	-6159.	1.7859E-02	-1463.92	
539.03	23450.	-6319.	1.6292E-02	-1324.38	
539.00	23234.	-6364.	1.5848E-02	-1283.15	
538.50	19917.	-6854.	1.0252E-02	-677.51	
538.00	16430.	-7041.	6.2120E-03	-71.87	
537.00	9855.	-6507.	1.7119E-03	1139.42	
536.00	3820.	-4762.	2.2939E-04	2350.70	
535.00	435.	-1806.	2.5479E-06	3561.98	
534.53	0.	0.	0.0000E+00	4130.70	

## III.-SOIL PRESSURES

ELEVATION (FT)	< LEFTSIDE PRESSURE (PSF)>			<RIGHTSIDE PRESSURE (PSF)>
	PASSIVE	ACTIVE	ACTIVE	PASSIVE
562.00	0.	0.	0.	0.
561.00	0.	0.	0.	0.
560.00	0.	0.	0.	0.
559.00	0.	0.	0.	0.
558.00	0.	0.	0.	0.
557.00	0.	0.	0.	0.
556.00	0.	0.	0.	0.
555.00	0.	0.	0.	0.
554.00	0.	0.	0.	0.
553.00	0.	0.	0.	0.
552.00	0.	0.	0.	0.
551.25+	0.	0.	0.	0.
551.25-	0.	0.	0.	0.
551.18+	0.	0.	2.	32.
551.18-	0.	0.	2.	32.
551.00	94.	6.	7.	108.
550.18	535.	36.	31.	483.
550.00	629.	42.	36.	538.
549.71	766.	52.	44.	682.

## MADIWALL.EX2

549.36	936.	65.	54.	815.
549.00	1105.	77.	64.	968.*
548.00	1343.	107.	93.	1022.*
547.00	1416.	124.	122.	902.*
546.00	1514.	135.	150.	1024.*
545.00	1632.	146.	179.	1192.*
544.00	1760.	157.	207.	1377.*
543.00	1898.	168.	236.	1582.*
542.00	2036.	179.	265.	1809.*
541.00	2192.	190.	293.	2082.*
540.00	2380.	200.	322.	1980.*
539.65	2445.	202.	66.	1304.
539.58	2463.	203.	0.	1128.
539.50	710.	50.	0.	1134.
539.43	713.	0.	0.	1140.
539.15	724.	0.	0.	1167.
539.03+	1031.	0.	14.	1179.
539.03-	728.	0.	14.	1179.
539.00	1031.	63.	18.	1182.
538.50	8218.	445.	865.	5794.
538.00	8464.	618.	985.	9315.
537.00	2786.	217.	410.	4797.
536.00	3010.	221.	433.	4197.
535.00	3039.	226.	453.	4038.
534.53	3061.	232.	465.	4061.
534.00	3204.	240.	476.	3949.

**Mad Creek** - Two foot raise of I-wall, hydraulic load starts at top of 2 foot raise. Moments and shears were determined with CWALSH, filename MADIWALL.IN2. Soil properties were chosen from typical values found in text books and borings from the area. A wall section with the least embankment on the unprotected side was used.

#### Internal Stress Checks (Bending and Shear of Concrete and Sheet Pile)

##### Given :

$$\text{psf} = \frac{\text{lbf}}{\text{ft}^2} \quad \text{psi} = \frac{\text{lbf}}{\text{in}^2} \quad \text{kip} = 1000\text{lbf} \quad \text{ksi} = 1000 \frac{\text{lbf}}{\text{in}^2} \quad \text{pcf} = \frac{\text{lbf}}{\text{ft}^3} \quad \text{Global conversions}$$

$$f_c := 4\text{ksi} \quad \text{Concrete compressive strength}$$

$$\gamma_w := 62.5\text{pcf} \quad \text{Unit weight of water}$$

$$E_s := 29500\text{ksi} \quad \text{Modulus of elasticity for steel}$$

$$f_y := 60\text{ksi} \quad \text{Yield strength reinforcing bars}$$

$$d_{5\text{bar}} := \frac{5}{8}\text{in} \quad \text{Diameter of vertical reinforcing bars}$$

$$h_{\text{barspace}} := 9\text{in} \quad \text{Horizontal spacing of wall tension reinforcing}$$

$$t_{\text{tow}} := 10\text{in} \quad \text{Top of wall thickness}$$

$$EL_{\text{tow}} := 562\text{ft} \quad \text{Elevation of top of wall}$$

$$EL_{\text{momconc}} := 549\text{ft} \quad \text{Concrete wall elevation to calculate section properties for moment capacity}$$

$$s_{\text{wall}} := \frac{1}{24} \quad \text{Slope of wall side}$$

$$t_{\text{cover}} := 2.5\text{in} \quad \text{Clear concrete cover over reinforcing}$$

$$d_{\text{moment}} := \left[ t_{\text{tow}} + 2 \cdot s_{\text{wall}} (EL_{\text{tow}} - EL_{\text{momconc}}) - t_{\text{cover}} - \frac{d_{5\text{bar}}}{2} \right]$$

$$d_{\text{moment}} = 20.188 \text{ in}$$

Depth of concrete wall from center of tension reinforcement to outermost compression fiber of concrete

$$b := 12 \text{ in}$$

Longitudinal length considered for analysis

### Check Moment Capacity of Concrete Portion of I-Wall

$$M_{\text{conc}} := 21940 \text{ ft-lbf}$$

Moment at base of concrete wall - from CWALSHT

$$L_f := 1.7$$

Live load factor

$$H_f := 1.3$$

Hydraulic load factor

$$M_u := L_f \cdot H_f \cdot M_{\text{conc}}$$

$$M_u = 48487.4 \text{ ft-lbf}$$

$$\phi_{\text{mom}} := 0.9$$

$$M_n := \frac{M_u}{\phi_{\text{mom}}}$$

$$M_n = 646.499 \text{ kip-in}$$

Factored Moment

$$d_{\text{req}} := \text{if } f_c = 3 \text{ ksi, } \sqrt{\frac{3.3274 \cdot \frac{M_n}{(\text{kip-in})}}{\frac{b}{\text{in}}}} \cdot \text{in, } \sqrt{\frac{2.4956 \cdot \frac{M_n}{\text{kip-in}}}{\frac{b}{\text{in}}}} \cdot \text{in}$$

Required depth of wall for moment.  
Equation good for 3ksi and 4ksi  
concrete and grade 60 reinforcing bars.

$$d_{\text{req}} = 11.595 \text{ in}$$

$$K_u := 1 - \sqrt{1 - \frac{M_n}{0.425 \cdot f_c \cdot b \cdot d_{\text{moment}}^2}}$$

$$K_u = 0.04$$

$$A_{\text{sreq}} := \frac{0.85 \cdot f_c \cdot K_u \cdot b \cdot d_{\text{moment}}}{f_y}$$

Required area of moment reinforcement

$$A_{\text{sreq}} = 0.545 \text{ in}^2$$

$$A_{sprov} := \frac{b}{h_{barspace}} \cdot \frac{\pi \cdot d_{5bar}^2}{4} \quad A_{sprov} = 0.409 \text{ in}^2 \quad \text{Existing area of moment reinforcement}$$

$$CK_{momconc} := \text{if}(A_{sreq} < A_{sprov}, \text{"GOOD FOR MOMENT"}, \text{"NO GOOD FOR MOMENT"})$$

$$CK_{momconc} = \text{"NO GOOD FOR MOMENT"}$$

#### Check Shear Capacity of Concrete Portion of I-Wall

$$\phi_{shear} := 0.85$$

$$EL_{shearconc} := 549.71 \text{ ft}$$

Concrete wall elevation to calculate section properties for shear capacity

$$d_{shear} := \left[ t_{tow} + 2 \cdot s_{wall} (EL_{tow} - EL_{shearconc}) - t_{cover} - \frac{d_{5bar}}{2} \right]$$

$$d_{shear} = 19.478 \text{ in}$$

Depth of concrete wall from center of tension reinforcement to outermost compression fiber of concrete

$$V_c := 2 \cdot \sqrt{\frac{f_c}{\text{psi}}} \cdot b \cdot d_{shear} \cdot \frac{\text{lbf}}{\text{in}^2} \quad V_c = 29.565 \text{ kip}$$

$$V_{conc} := 4140 \text{ lbf}$$

Shear force at EL 549.71  
from CWALSHT output

$$V_u := L_F \cdot H_F \cdot V_{conc} \quad V_u = 9.149 \text{ kip}$$

Factored shear force at EL 549.71

$$CK_{shearconc} := \text{if}(V_u < \phi_{shear} \cdot V_c, \text{"GOOD FOR SHEAR"}, \text{"NO GOOD FOR SHEAR"})$$

$$CK_{shearconc} = \text{"GOOD FOR SHEAR"}$$

#### Check Moment Capacity of Sheet Pile Portion of I-Wall

$$M_{steel} := 35689 \cdot \text{ft} \cdot \text{lbf}$$

Maximum moment in sheet pile at EL 543  
from CWALSHT output

$$c_{\text{steel}} := 6\text{in}$$

Distance from NA to outermost tension fiber

$$I_{\text{steel}} := 184.2 \cdot \text{in}^4$$

Moment of inertia of PZ27 on a per foot basis

$$\sigma_{\text{steel}} := \frac{M_{\text{steel}} \cdot c_{\text{steel}}}{I_{\text{steel}}}$$

$$\sigma_{\text{steel}} = 13.95 \text{ ksi}$$

$$\sigma_{\text{allow}} := 25 \cdot \text{ksi}$$

Allowable tensile strength of A328 sheet piling

$$CK_{\text{momsteel}} := \text{if}(\sigma_{\text{steel}} < \sigma_{\text{allow}}, \text{"GOOD FOR MOMENT"}, \text{"NO GOOD FOR MOMENT"})$$

$$CK_{\text{momsteel}} = \text{"GOOD FOR MOMENT"}$$

#### Check Moment Capacity of Sheet Pile Portion of I-Wall

$$V_{\text{steel}} := 7041 \text{ lbf}$$

Maximum shear in sheet pile at EL 538 from  
CWALSHT output

$$A_{\text{shear}} := \frac{3}{8} \cdot \text{in} \cdot 12 \text{ in}$$

Approximate web area of sheet pile

$$\sigma_v := \frac{V_{\text{steel}}}{A_{\text{shear}}}$$

$$\sigma_v = 1.565 \text{ ksi}$$

Shear stress in web of sheet pile

$$F_y := 39 \text{ ksi}$$

Yield stress of A328 steel

$$\sigma_{\text{vallow}} := 0.4 \cdot F_y$$

$$\sigma_{\text{vallow}} = 15.6 \text{ ksi}$$

Allowable shear stress of A328 steel

$$CK_{\text{vsteel}} := \text{if}(\sigma_v < \sigma_{\text{vallow}}, \text{"GOOD FOR SHEAR"}, \text{"NO GOOD FOR SHEAR"})$$

$$CK_{\text{vsteel}} = \text{"GOOD FOR SHEAR"}$$

